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ORIGINAL CONTRIBUTION

Activities of Daily Living and Cardiovascular Complications Following Elective, Noncardiac Surgery

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Background: Algorithms for preoperative cardiac evaluation prior to noncardiac surgery use indices of the metabolic equivalent of activities of daily living (METs). We evaluated METs as a predictor of cardiac complications following elective, noncardiac surgery.

Methods: A study was performed in an outpatient university preadmission center. METs were estimated prospectively for 5939 inpatients admitted for elective, noncardiac surgery who underwent a preanesthetic assessment within two months prior to surgery. Cardiac outcomes were retrieved retrospectively from relational databases. Outcomes included death, myocardial infarction, acute congestive failure, arrhythmias, cardiac arrest, acute ischemia, acute renal failure, stroke, respiratory failure, severe hypertension, peripheral vascular occlusion, and pericardial effusion. Adverse outcomes were correlated with age, gender, surgical procedure, activities, and the American Society of Anesthesiologist's Physical Status (ASA-PS) using receiver operator characteristic curve analysis.

Results: 94 of 5939 (1.6 percent) patients had cardiac complications; 16 died, six from their cardiac complication. 38.3 percent of complications occurred following vascular surgery. Using a multinomial logistic regression analysis, both age and physical status were highly significant predictors ($p < 0.001$) but METs was not ($p = 0.793$). Receiver operator characteristic (ROC) curves were used for predictive value of variables. Area of the curves for age versus cardiac complications and death were 0.814 and 0.782; for physical status, 0.744 and 0.803; for METs, 0.664 and 0.524. Conclusions: METs are not a reliable index for the prediction of adverse cardiac events following elective, noncardiac surgery. Age and physical status are more predictive. Adverse cardiac outcomes are most frequent following vascular surgery.

INTRODUCTION

As the longevity of the population increases, more and more elderly patients are being scheduled for elective, noncardiac surgery [1]. The higher prevalence of cardiovascular disease in the older population increases the risk of perioperative cardiovascular complications and death.

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[b] Abbreviations: ACC/AHA, American College of Cardiology and the American Heart Association; MET, metabolic activity of daily living; ASA-PS, American Society of Anesthesiologist's physical status; ROC, receiver operator characteristic.

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Noninvasive cardiac tests that mimic the stress of anesthesia and surgery have been developed to estimate the cardiovascular risk associated with these procedures. However, the predictive value of these tests is not high and their routine use dramatically increases the cost of healthcare [2, 3, 4].

The American College of Cardiology and the American Heart Association (ACC/AHA) have addressed these issues with the development of the *ACC/AHA Guidelines for Perioperative Cardiovascular Evaluation for Noncardiac Surgery* for the preoperative cardiac evaluation of patients with cardiovascular disease who are presenting for elective, noncardiac surgery [5]. The *ACC/AHA Guidelines* recommend a strategy of stratification based on the presence or absence of clinical indicators, the proven risk of the proposed surgery, and an estimation of metabolic equivalent of activities of daily living (METs). Epidemiological studies and controlled clinical trials have substantiated the value of both the clinical indicators of cardiovascular disease and the risk of various types of surgery [6, 7]. However, the correlation of METs with adverse cardiac outcomes has not been validated in a prospective study of a large number of patients scheduled for a variety of noncardiac surgical procedures.

We estimated METs prospectively during a preanesthetic assessment in advance of the patient's elective admission to the hospital for inpatient, noncardiac surgery (ambulatory surgery patients were not included). In this report, we will analyze the predictive value of METs for perioperative cardiovascular morbidity and mortality.

MATERIALS AND METHODS

An electronic medical record was implemented in the Preadmission Center at Yale-New Haven Hospital in 1996 for the preanesthetic evaluation of surgical patients scheduled for same-day admission to the hospital. Patients scheduled for ambulatory surgery (same day admission and discharge) were not included. Evaluations were performed by an anesthesiologist during a clinic visit within eight weeks of admission for surgery. A template was included in the electronic record to document the physician's estimation of patients' METs, based on historical reporting by the patients, in accordance with the criteria of the *ACC/AHA Guidelines* and the Duke Activity Status Index (Table 1) [8]. The electronic record also recorded patient demographics, medical history, limited physical exam, diagnoses, and proposed surgery. Data were recorded in a relational database using hand-held tablet computers in a client-server network. The medical history and limited physical examination allowed determination of ASA-PS (Table 2) [9], an established index that correlates well with adverse perioperative outcomes [10].

The Human Investigation Committee of the Yale School of Medicine approved this study. Because of the observational nature of the study, the Committee advised that patient informed consent for participation was not necessary.

There were 8639 patient visits to the Preadmission Center from November 1996 to March 1999. The patients were scheduled for surgical procedures including intracranial, intrathoracic, intra-abdominal as well as other operations. Of these visits, there were 6746 corresponding hospitalizations identified in database utilized by the hospital for administrative purposes. The remaining 1893 patients did not have a record of being admitted within two months after their visit to the Preadmission Center. Cardiac surgery was performed on 807 of the 6746 patients and these patients were excluded from the study. Thus, 5939 patients form the sample for this study. Patients seen in the program

Table 1. METs Scale[a].

Less than 4 METs	• Self care of oneself • Eat, dress, use toilet • Walk indoors around the house • Walk 1 to 2 blocks on ground level at 2 to 3 mph
4 METs	• Climb a flight of stairs or walk up a hill • Walk on level ground at 4 mph • Do light yard work
6 METs	• Do heavy work around the house like scrubbing floors or moving furniture • Do moderate yard work
8 METs	• Participate iin moderate recreational sports • Daily exercise program • Do heavy yard work
10 METs	• Participate in strenuous sports • Prolonged aerobic exercise

[a] The *ACC/AHA Guidelines for Perioperative Cardiovascular Evaluation for Noncardiac Surgery* criteria for METs were modified for use in this study in an attempt to distinguish

Table 2. American Society of Anesthesiologists Physical Status Classification.

ASA-PS	Criteria	Example
I	Healthy patient with no physical, biochemical, or emotional disease	Healthy patient for elective cosmetic surgery
II	Mild or moderate systemic disease without functional impairment	Elective cholecystectomy in a patient with controlled hypertension
III	Moderate or severe systemic disease with functional impairment	Elective colectomy in a patient with stable angina
IV	Severe systemic disease that is a constant threat to life	Coronary artery bypass in a patient with unstable angina
V	Moribund patient not expected to survive more than 24 hours without	Patient with a ruptured abdominal aortic aneurysm
E[a]	Any emergency procedure	Patient with perforated colon for diverting colostomy

[a] E is added as a modifier for the other ASA-PS classes, e.g., IE, IIE, IIIE, IVE. All patients classified as ASA-PS V will have the modifier E added.

Table 3. Surgical procedures associated with cardiac complications[a].

Surgical procedure	Number of patients who had cardiac complications (percent)	Number of patients who had procedure (percent complication rate)
Abdominal aortic aneurysm	17 (18.2)	53 (32.1)
Carotid endarterectomy	12 (12.8)	205 (5.9)
Femoral bypass	7 (7.4)	110 (6.4)
Colectomy	5 (5.3)	223 (2.2)
Total knee arthroplasty	6 (6.4)	177 (3.4)
Hysterectomy	6 (6.4)	917 (0.65)
Arteriovenous fistula	4 (4.3)	37 (10.8)
Laminectomy	4 (4.3)	429 (0.9)
Gastrectomy	4 (4.3)	26 (15.4)
Lobectomy	4 (4.3)	85 (4.7)
Partial hepatectomy	3 (3.2)	20 (15.0)
Colostomy closure	3 (3.2)	30 (10.0)
Ventral herniorrhaphy	3 (3.2)	84 (3.6)
Laparoscopic hiatal herniorrhaphy	2 (2.1)	13 (15.4)
Mastectomy	2 (2.1)	185 (1.1)
Radical vulvectomy	2 (2.1)	11 (18.2)
Total hip arthroplasty	2 (2.1)	189 (1.1)
Radical nephrectomy/revascularization	1 (1.1)	12 (8.3)
Functional neck dissection	1 (1.1)	75 (1.3)
Artificial urinary sphincter	1 (1.1)	19 (5.3)
Laparoscopic cholecytectomy	1 (1.1)	199 (0.5)
Transurethral prostatectomy	1 (1.1)	69 (1.4)
Distal pancreatectomy	1 (1.1)	33 (3.0)
Transphenoidal hypophysectomy	1 (1.1)	26 (3.8)
Pelvic exenteration	1 (1.1)	5 (20.0)

[a] Surgical procedures performed on patients who developed cardiovascular complications. Complications were most common following vascular surgery when n > 100. The abdominal aortic aneurysm group includes patients who received aorto-iliac grafts for occlusive disease. The hysterectomy group includes three patients who underwent radical hysterectomy.

were scheduled for the full range of surgical services provided at a tertiary care medical center. Of these patients, 2453 underwent high risk-surgery as defined by the Cardiac Risk Stratification for Noncardiac Surgical Procedures, ACC/AHA Guidelines, 2789 underwent intermediate risk procedures, 683 had low risk procedures, and 14 had no operative procedure during their hospitalization.

Perioperative cardiac morbidity and mortality, and length of stay were determined from the hospital's inpatient financial and medical records. To determine cardiac complications, the administrative database was searched for patients who were discharged with cardiovascular diagnoses (ICD-9-CM codes 410 through 414.9). One investigator (RW) reviewed the discharge summaries of those patients with cardiac discharge diagnoses and determined which diagnoses actually represented cardiac complications occurring during the hospitalization rather than preexisting conditions.

Forty-two physicians performed preanesthetic assessments during the period of data collection. Physician identity was recorded in each database record. This allowed a quantitative analysis of the distribution of each physician's assessment for both ASA-PS and METs.

Descriptive statistics (mean, median, and standard deviation) were determined for patient demographics, and the t-test used for comparison. Linear correlations and multinomial logistic regression were used to determine the statistical correlation among outcomes and patient age, METs, and ASA-PS, with both univariate and multivariate analyses. Receiver operator characteristic (ROC) curves were constructed to provide visual display of the approximate statistical utility of the potential outcome predictors. All calculations were done using SPSS (SPSS version 9, SPSS, Inc., Chicago).

RESULTS

Of the 5939 patients in our study, 62.6 percent were female and 37.4 percent were male. The age ranged from 16 to 96 years with a mean of 54.9 years. Preoperative ASA-PS scores were available on 99 percent of the patients. Pre-operative METs scores were available on 95.4 percent of the sample. Analysis of the database indicates that the age and ASA-PS for the subset of patients with missing data for METs was the same as that for the group with documented METs.

Perioperative cardiovascular morbidity and mortality were observed in 94 patients who underwent elective, noncardiac surgery (Table 3). Thirty-three patients (35.1 percent) had two cardiovascular complications while 10 patients had three (10.6 percent). There were 17 deaths in the entire group of patients who had surgery, but only 6 patients (6.4 percent) died as a direct result of their perioperative cardiovascular complications. There was a significant difference in age of patients who had cardiovascular complications (median 71.4 years, standard deviation 8.7 years) and those who did not (median 54.6 years, standard deviation 15.7 years). While there were more women in the group without cardiac complication (62.9 percent vs. 37.1 percent), there were significantly more men than in the group who had cardiac complications (54.3 percent vs. 45.7 percent).

Vascular surgical procedures were performed in 38.3 percent of patients who had cardiovascular complications. Most of these (18.2 percent) had undergone abdominal aortic replacement. These pro-

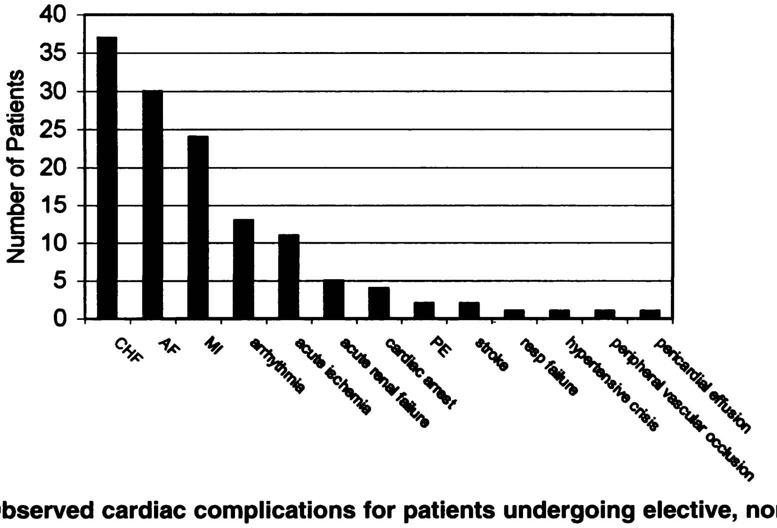


Figure 1. Observed cardiac complications for patients undergoing elective, noncardiac surgery.

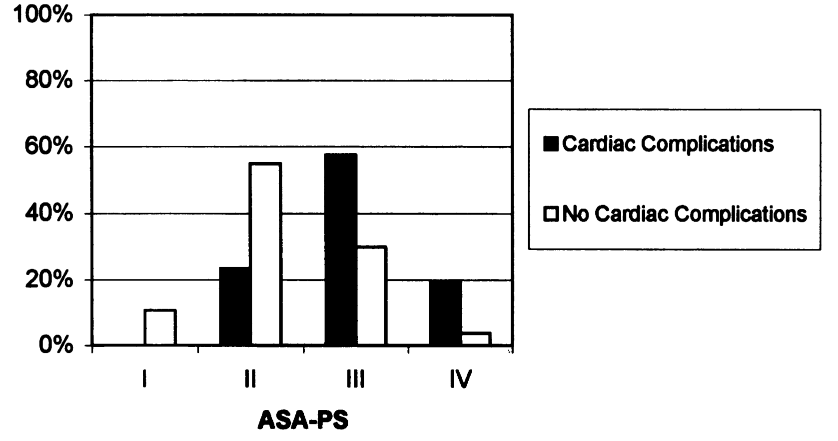


Figure 2. The American Society of Anesthesiologists physical status classification of patients.

cedures had the highest incidence of cardiovascular complications (32.1 percent). Similarly, carotid endarterectomy was performed in 12.8 percent of patients who had cardiovascular complications, but the incidence was somewhat lower (5.9 percent). Femoral artery bypass procedures were performed in 7.4 percent of patients who had complications and the incidence was 6.4 percent.

The most frequent complication was acute congestive heart failure, seen in 37 patients, followed by atrial fibrillation in 30, acute myocardial infarction in 24, other arrhythmias in 13, and acute ischemia without myocardial infarction in 11 (Figure 1). Five patients required urgent or emergency coronary revascularization (3 coronary artery bypass grafting, 2 angioplasty). Of the six patients that died, 3 sustained a myocardial infarction, 2 had a primary cardiac arrest (one with myocardial infarction), and 2 died from acute congestive heart failure.

The majority of patients in the cardiac complication group (57.4 percent) were rated as ASA Physical Status III (Figure 2) while METs were estimated as "less than 4" for 46.8 percent. Low METs were more common in ASA III and IV patients while Higher levels of METs were seen in ASA I and II patients. The majority of the patients in the group without cardiac complications were rated as ASA-PS II (54.5 percent) while there was an even distribution of estimated METs from "less than 4" through "METs = 8." A proportion of patients included in the study (12.6 percent) had surgery (hip or knee arthroplasty, lumbar laminectomy or fusion, and major amputation) for conditions that potentially could limit activities of daily living for reasons other than limited cardiovascular reserve.

Patient age was a strong predictor of cardiac complications, death, and lengths of stay. Receiver operator characteristic (ROC) curves were constructed to graphically demonstrate the sensitivity and specificity of age, METs, and ASA-PS for cardiac complications and death (Figures 3a-f). The ROC curves indicated significantly better sensitivity and specificity for age and ASA-PS than for METs for both for cardiac complications and as well as for death. Using the variables patient age, ASA-PS, and METs to predict cardiac outcome, there was a statistically significant

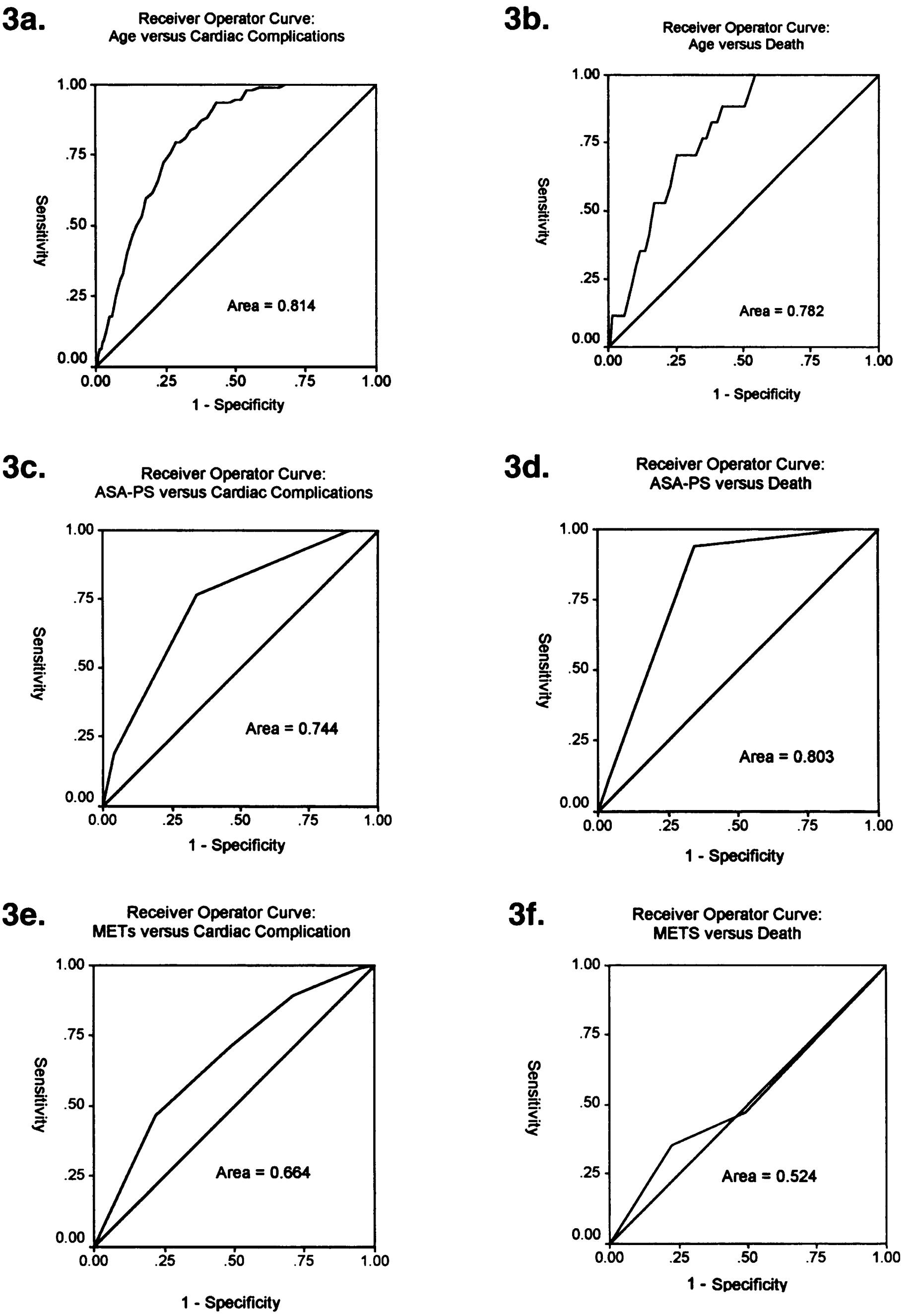
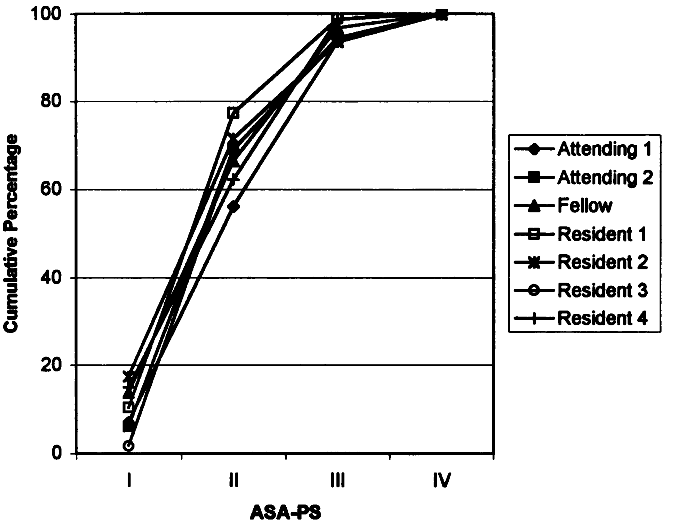


Figure 3. ROC curves for cardiac complications and death were constructed for patient age (3a and b), ASA-PS (3c and d), and METs (3e and f). ROC curves are constructed by plotting sensitivity of a test (Y-axis) against 1 minus the specificity of the test. The area under the plotted curve increases as sensitivity [true positive/(true positive + false negative)] and specificity [true negative/(false positive + true negative)] increase. A test that yields random results will have a ROC curve area of 0.5 while a curve with an area approaching 1.0 indicates very high sensitivity and specificity. ROC curve area was greatest for age versus cardiac complications and least for METs versus death.

4a.



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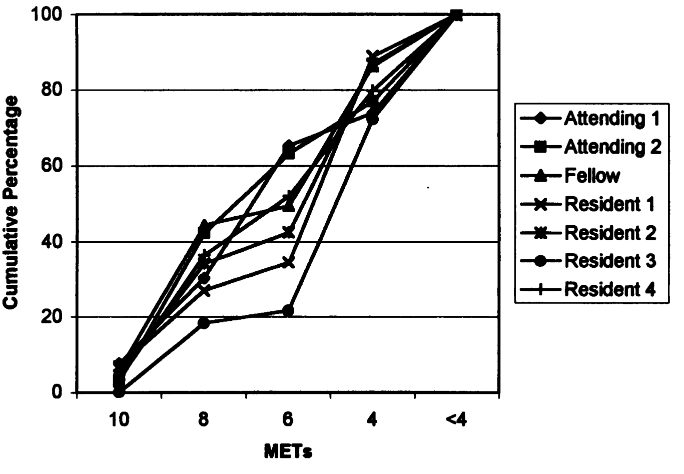

Figure 4a and b. Cumulative percentage of physicians' assessments of ASA-PS (Panel a) and METs (Panel b). The apparent difference demonstrated for seven physicians at METs levels of 4, 6, and 8 may indicate significant observer bias in the estimation of METs.

linear interdependence among the variables. Calculating bivariate correlation coefficients for age vs. ASA-PS, r = 0.369; for age vs. METs, r = 0.327; and for ASA-PS vs. METs, r = 0.394 (all with $p < .001$). With all three variables put into a multinomial logistic regression model, both ASA-PS and age are highly significant predictors ($p < .001$), but METs did not add significance to the model ($p = .793$). Even using reduced models, with only two of the three possible predictors to predict cardiac complications, METs did not achieve significance while age and ASA-PS always did. Only when METs was analyzed in a univariate model did it have significant predictive value.

The distribution of ASA-PS and METs determination was analyzed by physician for 7 physicians who performed more than 140 of the preanesthetic assessments in the database (Figures 4a and b). Qualitatively, there appeared to be more variation among physicians in the assessment of METs than there was for ASA-PS, possibly representing observer bias in estimating METs.

DISCUSSION

In the United States, the population will continue to grow from 275 million in 2000 to 347 million by the year 2030 [11]. Although this is the slowest growth in several decades, there will be 34.7 million people in the United States who are over the age of 65 years. In 1996, 14.5 million of the 40 million total surgical procedures performed in the United States involved patients aged 65 years or older. Nearly one-third of these, 5.4 million, underwent procedures on the cardiovascular system [12].

It is estimated that nearly 60 million Americans have one or more forms of cardiovascular disease and that cardiovascular disease accounts for more than 40 percent of all deaths in the United States. Coronary heart disease is the single leading cause of death in the United States today. Approximately 12 million patients in the United States have had a myocardial infarction or have symptoms of angina pectoris. New or recurrent myocardial infarction will occur in 1.1 million patients this year; one-third of these will be fatal [13]. Although death from cardiovascular diseases declined 34 percent from 1980 to 1990 [14], the actual number of deaths in the same period declined only 2 percent.

Goldman et al. [15] described one of the earliest strategies aimed at determining which patients are at highest risk of adverse cardiovascular events with elective surgery. It continues to be used more than 20 years later although others have suggested modifications, which include an assessment of functional capacity [16]. These modifications target the physiologic effects of comorbid disease on cardiac reserve. Often exercise testing is used to uncover limitations that are not recognized by a careful history determining the amount of stress that provokes angina pectoris or exertional dyspnea. However, in order to complete the modified risk index assessment, arterial blood gases as well as studies of renal and liver function are necessary. Noninvasive cardiac testing and, possibly coronary revascularization, are recommended for patient with intermediate or high index scores if they are to undergo intermediate or high-risk surgery. These recommendations are clearest for patients scheduled for intra-abdominal aortic surgery and are consistent with those of the American College of Cardiology and American Heart Association. Therefore, It is important to have available a means for determining risk without the expense and time involved in extensive testing. The need for preoperative cardiac testing is less clear for healthier patients undergoing intermediate- to low-risk (less than 5 percent) since the risk of coronary revascularization may be greater than that associated with the proposed surgery.

The *ACC/AHA Guidelines* stratify the need for preoperative cardiac testing on the basis of an estimation of the patient's activities of daily living expressed in METs. However, the predictive value of the clinical estimation of METs has not been validated in a prospective series of patient presenting for elective, noncardiac surgery and the value of this strategy has been questioned [17].

Preoperative assessment of cardiac risk is important because of the adverse consequences of unexpected cardiac complications following surgery. Length of stay and cost of treatment can escalate when patients require intensive care and invasive interventions for cardiac complications. More importantly, cardiac complications such as acute myocardial infarction, acute congestive heart failure, or serious arrhythmias are associated with high risk of death. These complications are believed to be more common for patients with advanced age as well as pre-existing conditions such as coronary artery heart disease, hypertension, severe valvular heart disease, and diabetes mellitus.

Our prospective study has shown that the predictive power of METs for adverse, perioperative cardiac outcomes is poor when its correlation with adverse cardiac outcomes is scrutinized in a multivariate analysis combined with ASA-PS and age. While METs has predictive power when used univariate analysis, when combined with age and ASA-PS in multivariate analysis it does not add to the predictive value.

The methodology we have chosen puts limits on our ability to interpret our data. We relied on the evaluation of METs by a variety of physicians including attending physicians, fellows, and residents in anesthesiology. Since patients were assigned randomly for preanesthetic assessment, observer bias can be estimated by an analysis of distribution of each practitioner's evaluation of ASA-PS and METs. We analyzed the evaluative process for the seven physicians with the most patient visits in our clinic. There was minimal difference in the distribution of ASA-PS assessments among the physicians working in our Preadmission Center (Figure 4a). There was virtually no disparity in percent of patients rated as ASA I or IV but there was more disparity in those rated ASA II and III. These differences were much more evident in the distribution of the estimated METs at the levels of 4, 6, and 8 METs, suggesting observer bias in the interpretation of patients' description of their daily activities (Figure 4b). Estimated METs of less than 4 was clearly evident for patients with severe disease or disability. Similarly, younger patients who participated in highly competitive sports were easily evaluated as having METs of 10 or more.

We made no attempt to estimate reporting bias caused by patients' descriptions of their normal daily activities. Patients often felt that they were very active but when queried about a daily exercise program or participation in recreational sports it was clear that their daily activities were actually fairly sedentary. Chronically ill patients freely admitted to a sedentary lifestyle while young, and very active patients could accurately describe the extent of their prolonged aerobic exercise programs.

These clinical impressions support our belief that observer and reporter biases contribute to the lack of sensitivity and specificity of estimated METs in predicting adverse cardiac outcomes. Observer and reporting biases have been eliminated in other studies by means of treadmill testing for determination of METs [18]. The use of exercise testing for the determination of METs probably would greatly improve the sensitivity and specificity of METs as a predictor of cardiac morbidity and death. However, the goal of the *ACC/AHA Guidelines* in recommending an algorithm for determining the need for noninvasive cardiac testing was to simplify the process and reduce the cost of preoperative cardiac assessments. Exercise testing might be useful for moderately active patients (estimated METs = 4-8) if they are to undergo high-risk surgery but routine exercise testing would not be practical in most settings because of the cost and inconvenience of rigorous exercise testing. In practice, many patients who are scheduled for high-risk surgical procedures, particularly vascular surgery, are sedentary and often are referred routinely for exercise testing as part of a cardiac stress test.

The discriminative value of METs may lie in the group of patients we have classified as "METs less than 4." These are sedentary patients who are able to provide their own daily care and ambulate without assistance. The predictive power of METs might improve if we expanded the study to distinguish subgroups such as those unable to ambulate without assistance, cardiovascular symptoms at rest, or cardiovascular symptoms with minimal physical activity. However, our aim was to validate the value of METs as used in existing algorithms.

Another criticism of our methodology is that we did not capture preoperative assessments on all eligible patients. The study group included 85 to 90 percent of the patients admitted to the hospital for elective surgery on the same day of their admission. The remaining patients were unable to keep Preadmission Center appointments for a number of reasons including lack of compliance, transportation problems, travel from long distances, and the need for urgent surgery. The latter group most often included patients referred from other hospitals for cardiac surgery following coronary angiography at the referring facility.

Finally, cardiovascular complications were determined by retrospective review of the discharge summary of all patients in the administrative database with new cardiac discharge diagnoses (ICD-9-CM 410 through 414). We chose this method because of its simplicity and the belief that it would include all cardiac complications that were important enough to warrant a determination that the patient had suffered an adverse cardiac outcome. We did not attempt to determine whether patients had experienced cardiac episodes such as occult ischemia, silent myocardial infarction, or transient arrhythmias. Thus the true incidence of adverse cardiac events may have been higher than what we observed.

Activities of daily living are limited in the presence of cardiovascular disease by angina pectoris, dyspnea, and claudication. Stroke with paresis is an indirect cause of limitation of activity secondary to cardiovascular disease. However, pain, vertigo, gastrointestinal distress and other manifestations of non-cardiovascular disease also limit METs and making it difficult to estimate cardiovascular reserve. To exclude immobility as a source of error, we analyzed the correlation of METs with cardiovascular morbidity and mortality excluding the subset of patients undergoing amputation, total joint arthroplasty, and spine surgery. ROC curves showed no substantial improvement. This finding was unexpected but it may reflect the poor sensitivity of METs as a predictor or it may have resulted from observer bias. Further our methodology did not allow us to distinguish among very low levels of METs (METs = 1, 2, or 3). Our goal, however, was to adhere as closely as possible to the ACC/AHA stratification of METs. It is possible that there is significant predictive value of METs if a study could discriminate activity at these lower levels.

In another preadmission program similar to ours, analysis of factors associated with adverse cardiac outcomes have been used to construct a simplified index for prediction of cardiac risk associated with major, noncardiac surgery [19]. Six preoperative criteria were given equal weight in estimating risk. The indices included high-risk surgery, history of ischemic heart disease, history of congestive heart failure, history of cerebrovascular disease, preoperative treatment of diabetes with insulin, and preoperative serum creatinine greater than 2.0 mg/dl. Incremental presence of the indices in a validation cohort showed cardiac complication rates increasing from 0.4 percent to 11.0 percent. The ROC curve area for the risk classification system was 0.806, a significant improvement over other indices, including ASA-PS, applied to the same cohort.

Mangano has also attempted to simplify the process for preoperative assessment of the patient with cardiac disease [20]. He has constructed a decision tree that uses the known presence of coronary artery disease, risk factors for coronary artery disease, and patients' functional status to determine the need for diagnostic testing and the preoperative treatment of patients for noncardiac surgery. However, his criteria for functional status are very similar to those in the ACC/AHA Guidelines and are subject to the same limitations of observer and reporter bias that we have encountered.

Preoperative estimation of METs as part of a preanesthetic assessment does not contribute to the ability to predict adverse perioperative cardiac outcomes. ASA-PS and patient age are much better predictors of cardiac complications, death, length of stay, and cost of hospitalization. The results of this study do not support the use of METs for stratification of the need for preoperative, noninvasive cardiac tests or modification of cardiac management as recommended in the guidelines of the ACC/AHA.

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